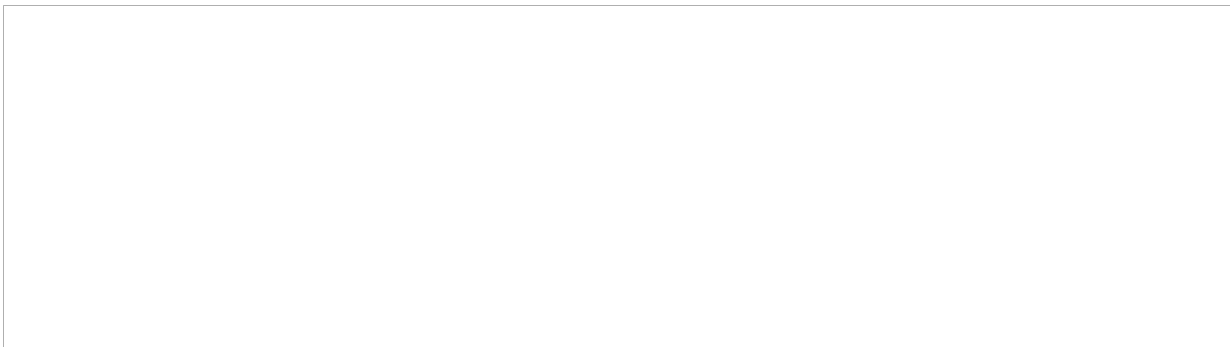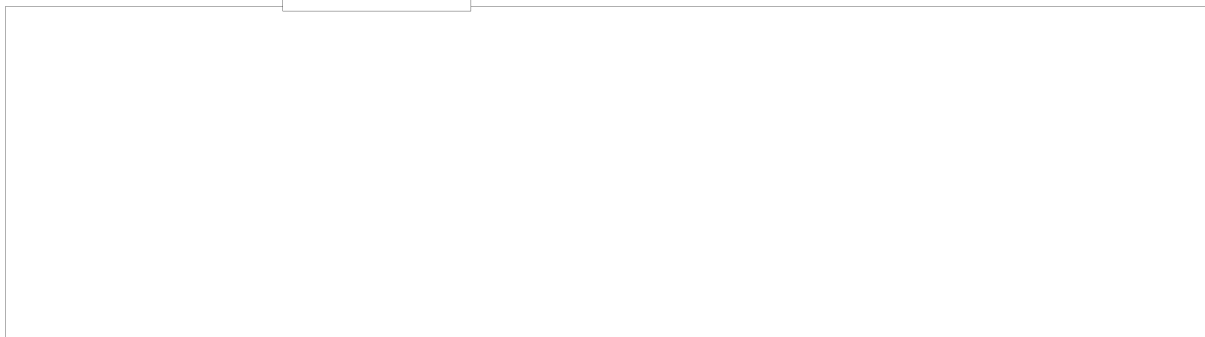Title:  A NEW ANOMALOSCOPE          USSR

G. N. Rautian

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## A NEW ANOMALOSCOPE

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[NOTE: The following is an article that originally appeared in the Technical Physics section of the periodical Doklady Akademii Nauk SSSR, Vol 73, No 1 (1 July 1950), pages 99-102, submitted by academician S. I. Vavilov on 8 May 1950. Apparently the anomaloscope is an optical instrument for studying color blindness and other visual defects or anomalies -- hence the name. For a description of related instruments, known by other names, see the English-language references given in the Bibliography of this article, which follows.]

[ ] In the works of the First All-Union Conference on physiological optics[1] a description was given of the "anomaloscope", which was invented by L. I. Demkina in cooperation with N. D. Nyuberg and later studied by I. Ye. Barbel[2]. All subsequent developments of apparatus for investigating the defects of color vision[3] have gone their various ways but not along the paths first contemplated.

Below we describe a new anomaloscope of a similar type and certain results obtained with it.

The main idea of this apparatus is defined as the "selective analysis or resolution (asunder)" of the sensitivity of each of the three Young receptors in the eye by a method in which one gradually varies the stimulus or excitation on one receptor being tested while subjecting the other two receptors to constant stimulus. Such an analysis is far from an experiment with clear simple conditions.

The experiments are based on the variation of color of one of the two comparative semifields in the apparatus, which variation is made to occur in such a way that the stimulus on only one particular receptor of the three receptors should vary during the test. (Note: Here is the fundamental dif-

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ference between the new anomaloscope and the one described by R. A. Houston in his book, Vision and Colour Vision, 1932, page 183.[4])

During the analysis a moment is fixed when the sense or consciousness is able to state definitely that a variation has taken place in the color of the semifield. In this way one establishes the magnitude of the threshold of color discrimination in one expression or another (depending upon how the apparatus is graduated) and thus obtains an immediate characteristic of sensitivity of the particular receptor being tested.

Figure 1 will clarify the principle governing the operation of the anomaloscope. The colors $O_1$, $O_2$, $O_3$, $O_4$ are represented here by vectors referred to the R, G, B axes of the basic physiological coordinate system. The fact that the components of the color vectors along the system's axes are proportional to the stimuluses acting on each of the three receptors in the eye is a unique peculiarity of this physiological coordinate system in comparison with other coordinate systems that are linearly dependent. This fact motivates its selection in this case.

Of the three coordinates $\alpha_1$, $\beta_1$, $\gamma_1$ of color $O_1$ in the following expression $\vec{O}_1 = \alpha_1\vec{R}_0 + \beta_1\vec{G}_0 + \gamma_1\vec{B}_0$, two coordinates, for example $\beta_1$ and $\gamma_1$, are kept constant in all colors $O_2$, $O_3$, $O_4$ (which colors in figure 1 represent various phases or stages of variation of color $O_1$ in the apparatus; whereas the only variable is the first coordinate $\alpha$, which defines the stimulus on the receptor corresponding to the R axis. Otherwise, the directions in which the initial colors must vary during all three tests must be parallel to the corresponding axes of the basic physiological system. Obviously knowledge of these axes is of significant value for the solution.

It should be noted, incidentally, that when we applied the basic physiological system proposed by Judd[5] in 1943-4 to calculate the color of the anomaloscope, the apparatus refused to operate, thus demonstrating the incorrectness of this system.

Now, as a result of the works of Ye. N. Yustova[6] we possess considerably more accurate knowledge of the axes of the basic physiological system

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and hence better knowledge of the spectral curves of sensitivity of the eye's receptors, than in 1934 when only the inaccurate system of Kening-Ives (but even more accurate than Judd's) was at the disposal of the inventors of the anomaloscope. Correspondingly, one can conduct the tests on the basis of an accurate calculation with sure observance of the condition of constant stimulation on two of the three receptors.

The internal structure of the new anomaloscope is schematically shown in figure 2. The color of one of the semifields observed in the ocular is determined by one or other of the color filters $F_1$, $F_2$, $F_3$ disposed along the path between lenses $L_1$ and $L_2$ which project part of the wall of the diffusion illuminator O on to the white screen $S_1$. The variable light of another semifield is determined by the position of the mobile frame W with six color filters across the openings of the lenses L' and L" in the light path II, which in a similar manner project the same part of the illuminator O on to the screen $S_2$. Three of these six light filters repeat accurately the light filters $F_1$, $F_2$, $F_3$ of beam I and in the beginning of each test they are placed in turns between the lenses L' and L". In this manner is the test set up each time with the observation of two semifields which are illuminated physically in completely identical ways. Under these conditions of complete visual equality of both semifields, the person being tested can state what defect his eye may possess. One and the same initial reading on the scale of the apparatus is thus ensured; the reading can be equated to zero since the null difference with respect to color corresponds to it. This is one of the original peculiarities of the above-described anomaloscope.

The remaining three of the six light filters F', F", F"' determine the final color of the three tests, when they are placed completely across the openings of the lenses L' and L" in the path of the beam.

All intermediate colors can be obtained for intermediate positions of the mobile frame, when any of the light filters F', F", F"' and the light filters indentical with $F_1$, $F_2$, $F_3$ are simultaneously in the beam II together with a part of their surface. These color variations are attained by a corres/

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shift in the frame W with the light filter during rotation of the correspon-
ding handle. The transition from one test to another is effected during ro-
tation of the drum with the marks 1, 2, 3. Divisions of the circular scale
which shifts during rotation of the handle are computed in the small glass
window.

Such a reading permits one to fix (first ~~glance~~ in divisions of the
scale) the magnitude of the first threshold of color differentiation; that
is, the difference barely noticeable for the person being tested between
both semifields. The mean data for the group of normal observers give the
transition to the quantitative expression for the sharpness of color perception in
thresholds corresponding to the norm.

It is possible to graduate the scale of the apparatus also in the components
R, G, B along the axes of the basic physiological system, and then graduate
the relative magnitude of threshold stimulus: $R/R$, $G/G$, $B/B$ are establi-
shed by the indications or readings in the apparatus.

If the selection of the initial color (that is, selection of the light
filters $F_1$, $F_2$, $F_3$) in all three tests can be made arbitrary to a consider-
able degree, then relative to the final colors determined by the light fil-
ters F', F", F"' we have the conditions indicated earlier on the constancy
of any two coordinates of the three $(\alpha, \beta, \gamma)$ in the course of the entire
given test. Selection of the final colors which satisfy this condition is
greatly simplified when one uses light filters that are combined with re-
spect to the area of the two different glasses, for example, for the
purple-red, made out of red and blue glass (see figure 2). This is ano-
~~ther~~ original peculiarity of the new anomaloscope.

The course of tests on the new anomaloscope is simple and very brief.
The apparatus is prepared for the test by setting the drum at one or other
mark. The person being tested sees in the ocular a square field of a homo-
heneous primary color, which field is divided in two by a line. All that
is required from the tester is that he merely signal when he notes for the first
time a variation of the color in one of the semifields and at the same time
when the tester is turning uniformly the handle moving the frame. A single
such test takes not more than 3 seconds. A repetition of the tests from 3 to

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5 times permits one to obtain the required mean value of the threshold read-
ing (m). If the value taken as the norm ($m_0$) is divided by m, then one ob-
tains the sensitivity characteristic of the receptor being tested; that is,
the coefficient of increase ($m_0/m > 1$) or decrease ($m_0/m < 1$) of the testee's
sensitivity in comparison with the norm. It requires only few minutes to
conduct a full test of one person, including the preliminary explanation and
writing down of the results. The apparatus is thus especially convenient
for large-scale mass tests.

In conclusion let us give certain observations obtained on the anomalo-
scope during its testing.

1. In order to investigate the influence of color adaptation on the
magnitude of the first threshold we took an observer with normal color dis-
crimination for whom the following values, averaged over 10 readings, were obtained, of the
threshold after a five-second fixation and after a two-minute preliminary
fixation of the field of vision (a six-minute fixation also for the B test).

| R Test | | G Test | | B Test | | |
|---|---|---|---|---|---|---|
| 5 sec | 120 sec | 5 sec | 120 sec | 5 sec | 120 sec | 360 sec |
| 1.6 div | 1.3 div | 1.8 div | 1.4 div | 8.0 div | 10. div | 11.7 div |

This data permits one to conclude that duration of fixation of the field
vision, which duration holds true for an individual test, cannot influence the
result.

2. In order to verify the correctness of the choice of the light filters
in the third test (B), we observed above the magnitude of threshold for a
strongly decreased (to 0.3°) field of vision. As is known, the central part
of the fovea, for about 0.5° extension, possesses a tritanopic type of dichro-
matism[7]. Therefore for a very small field of vision, the normal observer must
be at least partially tritanopic, although not complete.

3. The values given below of the first threshold of an observer (in divisions
of the scale), which values were obtained for ordinary fields of vision and
for a small field of vision, verify completely this assumption and agree well
with our previous observations carried out by another method[8].

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| Field of Vision | R Test | G Test | B Test |
|---|---|---|---|
| $3.0^\circ$ | 2.2 div | 3.5 div | 8 div |
| $0.3^\circ$ | 4.0 div | 5.9 div | 46.9 div |

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6. Ye. N. Yustova, Doklady Akademii Nauk SSSR, 63, No 4 (1948); 65, No 5 (1949).

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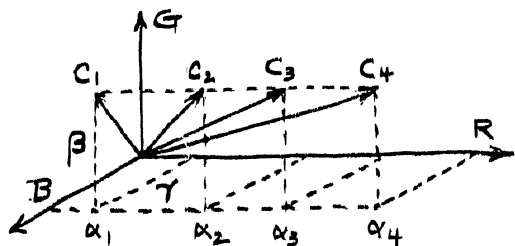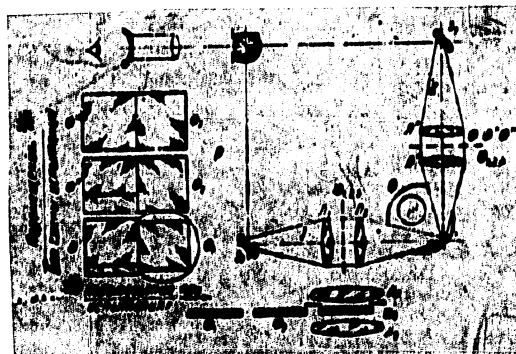8. G. N. Rautian and V. I. Demkina, Doklady 66, No 5 (1949).

APPENDIX



Figure 1.



Figure 2.

*Direction
of Shift
During Test

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